NASA TECHNICAL TRANSLATION NASA TT F-14,175

THE KOSMOS 243 INVESTIGATION OF MICROWAVE RADIATION OVER A CULTIVATED LANDSCAPE

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Translation of "Issledovaniye mikrovolnovogo izlucheniya so sputnika "Kosmos-243" nad kul'turnym landshaftom," Doklady Adademii Nauk SSSR, Vol. 201, No. 4, 1971, pp. 837-839.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 APRIL 1972

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ABSTRACT. Kosmos 243 findings on microwave radiation from the earth's surface, and soil temperature and moisture findings obtained by the Soviet Hydrometeorological Service, to determine cultivated soil parameters are discussed. The methodologies used are explained.

This paper presents the results of an analysis of the field of microwave radiation over the European part of the USSR. The analysis was made to establish the feasibility of determining the parameters of the terrestrial surface in a zone in which the surface is cultivated. The results of the Kosmos 243 measurements of microwave radiation [1], and the data on temperature and moisture obtained by station of the Hydrometeorological Service, and by agrometeorological stations, also were used. The European part of the USSR was selected because its cartographic materials and meteorological data were the best available. /837*

The radiometers installed in Kosmos 243 provided synchronized measurements of the radio brightness temperature, $T_{b,\lambda}$, for λ = 8.5, 3.4, and 0.8 cm at the subsatellite point. Space-time averaging during the measurements provided the brightness temperature, averaged for an ellipse with semiaxes of 33 and 25 km. The major semiaxis was oriented along the flight line. The noise response of the radiometers, converted into brightness temperatures, was about 0.7°K on 8.5 and 3.4 cm, and about 2°K on 0.8 cm. Two projections of the trajectory from the Black Sea to Obskaya Guba for 23 and 24 September were used for the analysis. Cloud cover was negligible while the satellite was in this region, and precipitation in the Central Volga region was minor, so there were no obstacles to measurements of radiation from the terrestrial surface.

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* Numbers in the margin indicate pagination in the foreign text.

The radio brightness temperature can be expressed, approximately, by

$$T_{b,\lambda} = A_\lambda T_{surface} + \Delta T_\lambda, \tag{1}$$

where

A_λ is the effective emissivity on wavelength λ, determined by the surface condition (roughness, nature of vegetation), and by the dielectric properties of the soil in a layer with a thickness of the order of the wavelength in which the radio radiation is produced.

The Fresnel formulas can be used to calculate A_λ when the case is that of an ideally smooth surface without vegetation, and the calculation reveals that in such case A_λ is greatly dependent on soil moisture. The second term, ΔT_λ, is associated with the nonisothermicity of the atmosphere, and when measurements are made over dry land, or even during light precipitation, its magnitude, and its variation, are no more than a few degrees for $\lambda \geq 0.8$ cm. Hence, the second term in the equation is smaller than the first by almost two orders of magnitude, so can be ignored when making approximate calculations.

Figure 1a is a correlation chart for assessing the connection between measured $T_{b,\lambda}$ values for $\lambda = 0.8$ cm, and the soil temperature, from meteorological station data. The calculation has shown that the correlation factor for $T_{b,\lambda}$ on 0.8 cm and soil temperature is 0.92.

Figure 1b shows the $T_{b,\lambda}/T_s = A_\lambda$ ratio as a function of the soil /838
moisture, ρ, characteristics, and is included to explain the effect of variations in moisture on the emissivity, A_λ, on this wavelength. Most of the agrometeorological stations estimate soil moisture visually and express it in numerical scale form, precluding establishment of absolute and relative soil moistures. Some of these stations (about 30 percent of them) determine the moisture as the ratio of the weight of the moisture to the weight of absolutely dry soil. This relative content has been used in this paper as the soil moisture characteristic, ρ, (Figure 1b). There are fewer points plotted in Figure 1b than in Figure 1a, and this stems from the fact that fewer stations measure ρ.

The data plotted in Figure 1 show that under the conditions prevailing for the observed range of soil moisture (from dry to fluid on the scale used by the agrometeorological stations), soil moisture has practically no effect on soil emissivity, A_λ, on the shortest of the wavelengths used, $\lambda = 0.8$ cm. This result is not unexpected for a cultivated landscape where roughness of the soil is considerable (as compared with the wavelength) and the soil usually is covered with vegetation. It therefore can be assumed in the case of satellite observations, when averaging is done for a large spot, that the radio radiation measurements on 0.8 cm (or on shorter wavelengths) will result in a determination of the temperature of the soil layer near the surface.

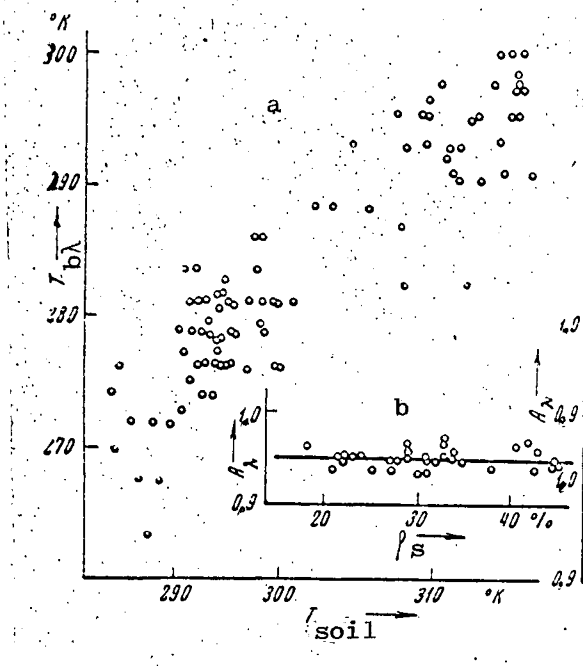

Figure 1

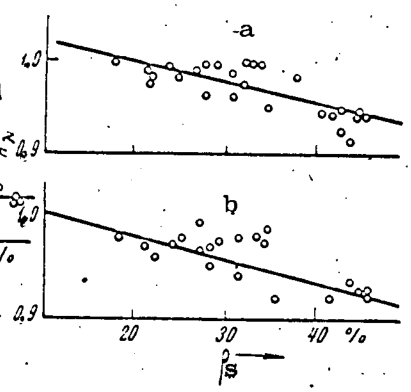

Figure 2

Figure 1a. a - radio brightness temperature, $T_{b,\lambda}$ on $\lambda = 0.8$ cm, in terms of soil temperature, T_s; b - the $A_\lambda = 0.8$ cm in terms of soil moisture characteristics.

Figure 2. The $T_{b,\lambda}/T_b = 0.8$ ratio on $\lambda = 3.4$ cm (a), and $\lambda = 8.5$ cm (b) in terms of soil moisture characteristics.

The effect of surface roughness and vegetation on the generation of radio radiation on the longer wavelengths probably is less, so it can be expected that soil moisture has a greater effect on surface radio radiation. Increase in soil moisture increases soil permittivity at radio frequencies, and this, in turn, results in a reduction in emissivity. This is shown in Figure 2, which presents brightness temperature values on 8.5 and 3.4 cm, equated to the brightness temperature on 0.8 cm, which is, as was established above, close to the soil temperature. Figure 2 reveals that as was expected, the moisture effect is /839
more pronounced on the longer wavelengths. It should be pointed out that the

drop in emissivity with increase in moisture on these wavelengths is less by a factor of 1.5-2 than it would be for a smooth surface, devoid of vegetation, with the same moisture.

The results obtained should be considered as preliminary, so their field of application is limited to the investigation of the cultivated landscape. Nevertheless, the experimental data obtained point to the possibility of using artificial earth satellites to obtain separate determinations of soil temperature and soil moisture from spectral measurements of departing microwave radiation in the millimeter and centimeter bands.

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Submitted
10 April 1971

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Translated for the National Aeronautics and Space Administration under contract NASw-2038 by Translation Consultants, Ltd., Arlington, Virginia.